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Use of Q-Switched Alexandrite Laser (755 nm, 100 nsec) for Removal of Traumatic Tattoo of Different Origins

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Background and Objectives: **Q-switched laser systems have been used for removal of tattoo-related carbon, graphite, and other particles. We assessed elimination of traumatic tattoos of different origin with Q-switched alexandrite laser in nine patients.**
Study Design/Materials and Methods: **Fluence threshold was determined and a spot test was made. Q-switched alexandrite laser, with a fluence range 4.5–8.0 J/cm^2 (mean, 7.16 ± 1.18), was used at 4–5-week intervals. Total treatment ranged from 3–12 sessions (mean, 6.1 ± 3.6 sessions). Double-pulse technique was used in black/black-bluish areas, but single-shot was applied to slate-gray pigment.**
Results: **More than 95% lightening was achieved in five patients after 5.2 ± 2.3 sessions, and >75% lightening in six subjects after 6.1 ± 3.1 sessions of treatment. Blacktop, surgical pen, and gravel tattoos presented a better response than gunpowder/fireworks tattoos (>95% vs. 68.7 ± 23.9% clearance), or tattoos of unknown origin (>95% vs. 62.5 ± 53% clearance). Epidermal splattering and pinpoint bleeding were observed in one case. No pigmentary alteration or scarring was seen.**
Conclusion: **The Q-switched alexandrite laser is a useful system for removal of traumatic tattoos of diverse origin. The best response (>95% clearance) was achieved in blacktop, surgical pen, and gravel tattoos, although an acceptable degree of lightening may be obtained in tattoos due to gunpowder or fireworks. Lasers Surg. Med. 25:445–450, 1999.**

Key words: alexandrite laser; traumatic tattoos; laser surgery

INTRODUCTION

Traumatic tattooing may originate from diverse exogenous pigments including, among others, amalgam, premarin, pencil point, petroleum products, fireworks particles, dust, dirt, sand, metal, glass, wood, gunpowder, blacktop, material suture, soot, or surgical pen [1–9]. However, carbon and graphite seem to be the major components of traumatic tattoos [4,10] resembling amateur tattoos [3]. The most frequent causes of traumatic tattooing are abrasion, avulsion, and laceration, which may lead to epithelium removal and pressurized penetration of dark particles into deep dermis, giving rise to black or blue tattoos depending on the depth of the pigment [3,10,11].

Achauer et al. [5] used a Q-switched ruby laser (694 nm, 15–40 nsec, 4-mm spot size; fluence range, 6–8 J/cm^2) for traumatic tattoo removal with successful results. Suzuki [3] obtained an excellent response after an average of 1.7 treatments with the Q-switched Nd:YAG laser (1,064

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TABLE 1. Characteristics of Patients

Case	Age	Sex	Localization	Material/mechanism
1	19	F	Sternum	Unknown/bone biopsy
2	17	F	Nose	Blacktop/abrasion
3	36	M	Eyebrow	Surgical pen/eyebrow hair implant
4	22	M	Face	Gunpowder/explosion
5	20	F	Nose	Gravel/fallen
6	16	M	Face, body	Firework/Explosion
7	26	F	Face, body	Unknown/butane explosion
8	26	F	Ear	Fireworks/explosion
9	55	M	Periocular	Fireworks/explosion

TABLE 2. Treatment Protocol

Patient	Fluence (J/cm^2)[a]	Interval (weeks)	Sessions
1	7.17 ± 0.29 (7.00–7.50)	4.14 ± 0.06	3
2	7.00 ± 0.0	4.4 ± 0.41	4
3	7.25 ± 0.25 (7.00–7.50)	4.75 ± 0.48	5
4	7.83 ± 0.31 (7.00–8.00)	4.46 ± 0.52	12
5	7.60 ± 0.55 (7.00–8.00)	4.5 ± 0.55	5
6	7.17 ± 0.55 (6.25–8.00)	4.55 ± 0.39	11
7	6.92 ± 0.14 (6.75–7.00)	4.2 ± 0.17	3
8	7.06 ± 1.26 (4.5–8.00)	4.53 ± 0.56	9
9	7.00 ± 0.0	4.4 ± 0.36	3

[a]Mean, standard deviation, and range.

nm, 5–7 nsec, 3-mm spot size). In a study by Alster [12], Q-switched alexandrite laser (755 nm, 100 nsec, 3-mm spot size) was effective in traumatic tattoo lightening after a mean of 3.7 treatment sessions with a mean fluence of 7.25 J/cm^2. The mechanisms of tattoo lightening are not completely understood. The high-level energy of Q-switched systems originates a thermal gradient that induces a shock wave capable of fragmenting pigment [13–15]. Transepidermal elimination and lymphatic drainage by macrophage activity as well as pigment optical property changes are other mechanisms involved [5,14].

We assessed the usefulness of alexandrite laser for elimination of traumatic tattoos of different causes in a series of 9 patients.

PATIENTS AND METHODS

The medical records of all patients who received Q-switched alexandrite laser treatment over the past 9 years were reviewed. A total of 17 patients underwent alexandrite laser treatment because of traumatic tattoos. Eight patients were excluded from this study because they did not complete treatment or were lost to follow-up. The remaining nine patients (three men, six women) had received from 3–12 sessions of Q-switched alexandrite laser (mean, 6.1 ± 3.58). Ages of the patients ranged from 16–55 years (mean, 26.33 ± 12.36 years), and skin phototype ranged from II–IV.

The characteristics of patients are shown in Table 1. Affected areas included the nose (n = 2), eyebrow (n = 1), ear (n = 1), face (n = 1), periocular region (n = 1), and sternum (n = 1). In the remaining two patients multiple areas were involved, including the face. Traumatic tattooing was related to fireworks in three patients, gunpowder in one, blacktop in one, gravel in one, surgical pen after eyebrow hair micrografting in one, bluish pigment after bone biopsy puncture in one, and dark particles after butane explosion in one. All cases presented a black, black-bluish, or slate-gray hue. One patient suffered blindness due to severe ocular trauma that obliged evisceration after butane explosion.

A Q-switched alexandrite laser, with 755-nm wavelength, 3-mm spot size, and a pulse duration of 100 ± 10 nsec (Candela Laser Corporation, Wayland, MA) was used. The same operator (A.C.-F.), using the same technique in all patients, performed the treatments. During the first visit, threshold fluence was determined and a spot test [16] was made on all patients. Treatment intervals ranged from 4–5 weeks. Energy fluence ranged from 4.5–8.00 J/cm^2 (mean, 7.16 ± 1.18). A decrease of 0.5 J/cm^2 was made in those cases of epidermal splattering or pinpoint bleeding [15]. The whole tattoo was completely covered. Overlapping was lower than 10% in slate-gray tattoos, but double-pulse, overlapping of 100%, was performed in those with black or black-bluish pigment [17]. The treatment protocol is shown in Table 2.

Topical anesthesia with lidocaine/prilocaine (EMLA®, Astra, Stockholm, Sweden) was applied 1 hour before the procedure, or local infiltration with mepivacaine 2% (Scandinibsa 2%®, Laboratorios Inibsa, S.A., Barcelona, Spain) was used. After each treatment, patients were instructed to wash the treated area with soft soap and water, and to apply mupirocin ointment (Bactroban®, SmithKline Beecham, S.A., Madrid, Spain), twice daily, for 1 week and then switch to a sunscreen (SPF 15) and maintain it until the following session. Pretreatment and posttreatment photographs were compared by two independent dermatologists unrelated to the study. Clinical response was scored according to a scale used for evaluation of tattoo lightening [16] (Table 3).

TABLE 3. Tattoo Lightening Scale [16]

Category	Lightening (%)
Clear	96–100
Excellent	76–95
Good	51–75
Fair	26–50
Poor	<25

RESULTS

Tattoo clearance according to treatment interval, session number, and type of material is shown in Tables 4 and 5. More than 95% clearance was obtained in five of the nine patients, whereas 76–95% clearance was achieved in six. The result was poor in only one patient (11.1%), who achieved <25% lightening. The mean lightening was 77.78 ± 29.17% after a mean of 6.1 ± 3.58 sessions, at a mean of 4.49 ± 0.44-week intervals.

The fluence ranged from 4.5–8.00 J/cm^2 (Table 2). Epidermal splattering and pinpoint bleeding were observed in one patient (case 8) during the first two treatments even at low fluences (4.50—5.50 J/cm^2). However, fluence increase was achieved with no side effects after the third session. Blacktop tattoo required the lowest fluence to obtain >95% lightening, while a slight increase in energy was necessary to achieve the same response in tattoos of unknown origin. Gunpowder, fireworks, and surgical pen tattoos required similar fluences to obtain equivalent lightng, while gravel tattoos showed the highest fluence requirements.

Alexandrite laser treatment was scheduled at 4–5-week intervals, but little difference was observed in this variable when considering the patients independently (Table 2), or grouped according to tattoo lightening (Table 4) or tattoo material (Table 5). Blacktop, surgical pen, and gravel tattoos required between 4–5 sessions of treatment with alexandrite laser to show a >95% lightening response. Gunpowder and fireworks tattoos needed more sessions to obtain a lightening response of 68.75 ± 23.93%, while tattoos of unknown origin showed a similar response after only three sessions of treatment. The right hemiface in case 4 cleared completely after 12 sessions, but black and black-bluish pigment remained on the left side. One patient (case 9) was satisfied with the result of laser treatment and rejected further sessions, while cases 4 and 7 are still being treated. No scarring or permanent pigmentary alterations were seen.

DISCUSSION

Our results are in contrast with those of Chang et al. [18]. In our series, patients needed more treatment sessions (6.1 ± 3.56) to obtain a similar response than in the study of Chang et al. [18]. Possible explanations for this difference are the limited number of patients included in the study, heavier pigment load, and greater extension of tattooed skin in some of our cases. The excellent response obtained in cases 1–3, 5 after a few sessions may have been due to the good coefficient absorption of Q-switched alexandrite laser wavelength by black and black-bluish pigment. In case 8 there was a black pigment tattoo, but complete lightening was observed after 9 sessions. Larger pigment particles might have been the reason that additional treatment was necessary. A shorter widthpulse (50 nsec) would have a greater photoacoustic effect on fireworks particles and would lead to an increase of tattoo fragmentation, which would be clinically documented as a better fading response [19]. Differences in clinical response after treatment with identical laser technique may have been due to deeper localization and heavier pigment load (Fig. 1).

Factors that may lead to incomplete tattoo removal are related to pigment properties, laser technique, and patient condition. Color, coefficient absorption, composition, load, depth of pigment, and age of tattoo are important predictors of clearance [16,20,21]. Dark colors absorb longer wavelengths, while light colors have an affinity for shorter wavelengths. Pigment chemical composition determines not only the final color but also the capacity for light absorption and pigment behavior in front of light. Pigments that contain titanium or ferric oxide in their composition may turn dark due to oxidation-reduction chemical reaction stimulated by Q-switched and pulsed laser systems [22,23]. Tattoo lightening is easier when carbon predominates in pigment composition [12], a circumstance that may explain the excellent response obtained in cases 1–3, 5, and 6. A heavy pigment load on the tattoo surface may act as a shield preventing laser penetration to deeper layers [17,24], and a double-impact technique may be a better approach in these cases due to the cumulative effect [17]. In addition, deep pigment may be partially and slowly eliminated by phagocytosis [13,25].

Most traumatic tattoos may be removed with 7.00–800 J/cm^2 using a Q-switched alexandrite laser and preserving epidermal integrity [12,26].

TABLE 4. Tattoo Lightening According to Treatment Interval and Number of Sessions

Category	Grade (%)	Patient (n)	Patient (%)	Interval (weeks)	Sessions
Clear	>95	5	55.6	4.5 ± 0.45	5.2 ± 2.28
Excellent	76–95	1	11.1	4.55 ± 0.39	11.0 ± 0.0
Good	51–75				
Fair	26–50	2	22.2	4.46 ± 0.48	7.5 ± 6.36
Poor	<25	1	11.1	4.2 ± 0.17	3.0 ± 0.0
Total		9	100.0	4.49 ± 0.44	6.1 ± 3.58

TABLE 5. Results According to Tattoo Material

Material	Fluence (J/cm^2)[a]	Interval	Sessions	Lightening (%)
Blacktop	7.00 ± 0.0	4.48 ± 0.52	4.0 ± 0.0	>95
Surgical pen	7.25 ± 0.25 (7.00–7.50)	4.75 ± 0.48	5.0 ± 0.0	>95
Gravel	7.6 ± 0.55 (7.00–8.00)	4.5 ± 0.55	5.0 ± 0.0	>95
Gunpowder/fireworks	7.32 ± 0.82 (6.25–8.00)	4.5 ± 0.44	8.75 ± 4.03	68.75 ± 23.93
Unknown	7.04 ± 0.25 (6.25–8.00)	4.12 ± 0.12	3.0 ± 0.0	62.5 ± 53.03

[a]Mean, standard deviation, and range.

Fluences higher than 8 J/cm^2 may lead to local pain, epidermal splattering, and pinpoint bleeding, increasing the risk of scarring and textural changes. However, hard, new, deep, and greater amounts of pigment may need higher energies and more treatments [20,27]. Dark colors are efficiently removed by all Q-switched laser systems [20], but the response of lighter tones is variable [28,29]. Phototypes darker than IV (Fitzpatrick scale) are at risk of pigmentary alterations after laser treatment [20]. Transient hypopigmentation is observed in 50% of cases, and usually appears after seven treatments with alexandrite laser [16]. Patients with hypertrophic scars or keloids are at risk of developing new scars on treated areas, particularly when a high-risk area is involved. In these cases, a decrease in energy is advisable.

The interval between sessions is very important. Although 4 weeks is an appropriate period for local healing to take place, longer treatment intervals [30] may result in further lightening, since phagocytosis pigment particles may lead to a decrease in local load pigment. This may correspond, at least in part, to what we have observed in those tattoos which gradually fade throughout the years even without any treatment. In this series there was little variation in session interval, and we could not notice any difference in the clinical response to alexandrite laser between 4- or 5-week intervals. We believe that other mechanisms that participate in tattoo lightening, such as pigment particle transepidermal extrusion and direct drainage to lymphatic circulation, may be taken into account only during the early post-treatment phase, and therefore would not be definitive factors in achieving a better lightening response if longer treatment intervals are scheduled.

Considerable cosmetic improvement was observed in patients with partial elimination of pigment, and it was the patients' own wish to stop treatment. We expect further clinical response in cases 4 and 7 that are still under treatment. Heavy-load pigment tattoos of different sizes on various anatomical areas were present in case 6, a fact that might have contributed to a slow response. Those cases with granulomatous reaction to tattoo pigment may benefit from surgical excision. The risk of ignition of gunpowder/fireworks tattoos must be considered as a possible side effect during Q-switched alexandrite laser treatment, and measures should be taken in order to guarantee the physician's safety as well as to prevent scarring in the patient [31].

In spite of different origins, black, black-bluish, and slate-gray traumatic pigments were efficiently removed by alexandrite laser; blacktop, surgical pen, and gravel tattoos required fewer treatment sessions to clear. Gunpowder and fireworks tattoos showed a slower but acceptable response. We conclude that alexandrite laser is a useful technique for removal of traumatic tattoos of different origins with minimal side effects and no complications, when appropriate fluence is used at 4–5-week treatment intervals.

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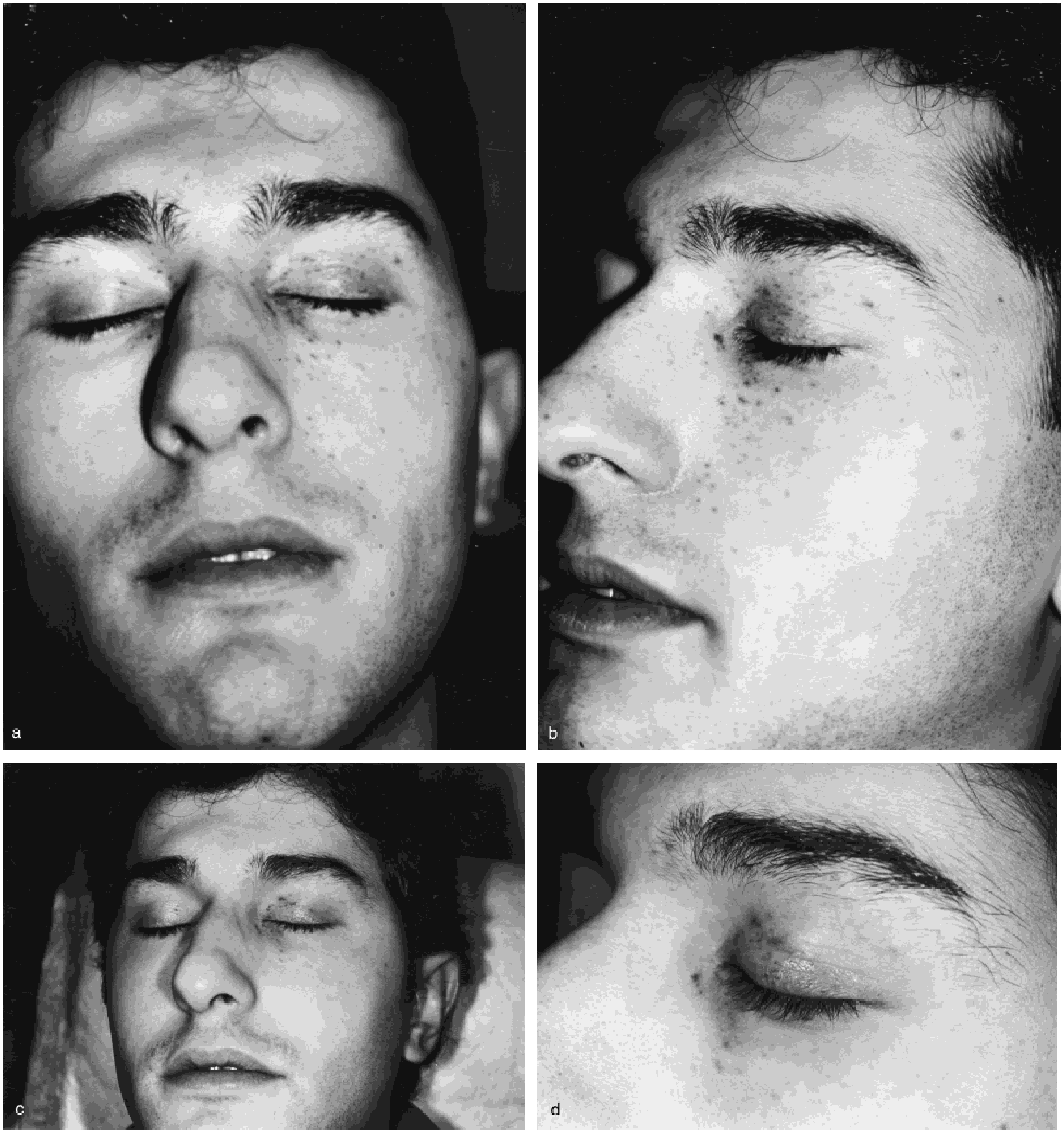

Fig. 1. Case 4. Before (**a,b**) and after (**c,d**) 12 treatment sessions with alexandrite laser. Compare right and left sides of face.

REFERENCES

1. Dello Russo NM. Esthetic use of a free gingival autograft to cover an amalgam tattoo: report of case. J Am Dent Assoc 1981;102:334–335.
2. Perusse R, Morency R. Oral pigmentation induced by premarin. Cutis 1991;48:61–64.
3. Suzuki H. Treatment of traumatic tattoos with the Q-switched neodymium:YAG laser. Arch Dermatol 1996; 132:1226–1229.
4. Ashinoff R, Geronemus RG. Rapid response of traumatic and medical tattoos to treatment with the Q-switched ruby laser. Plast Reconstr Surg 1993;91:841–845.
5. Achauer BM, Nelson JS, Vander Kam VM, Applebaum R. Treatment of traumatic tattoos by Q-switched ruby laser. Plast Reconstr Surg 1994;93:318–323.
6. Hohenleutner U, Landthaler M. Traditional tattooing of the gingiva: successful treatment with the argon laser. Arch Dermatol 1990;126:547.
7. Goertz J, Goos M. Traditional tattooing of the gingiva: an

Eritrean folk practice. Arch Dermatol 1988;124:1018–1019.
8. Hanke CW, Conner CA, Probst EL Jr, Fodak AA. Blast tattoos resulting from black powder firearms. J Am Acad Dermatol 1987;17:819–825.
9. Zamboni WA, Eriksson E, Zook EG. Management of acute facial powder burns. Ann Plast Surg 1987;19:158–161.
10. Apfelberg DB, Manchester GH. Decorative and traumatic tattoo biophysics and removal. Clin Plast Surg 1987;14: 243–251.
11. Böhler K, Müller E, Huber-Spitzy V, Schuller-Petrovic S, Knobler R, Neumann R, Seidl K. Treatment of traumatic tattoos with various sterile brushes. J Am Acad Dermatol 1992;26:749–753.
12. Alster TS. Successful elimination of traumatic tattoos by the Q-switched alexandrite (755-nm) laser. Ann Plast Surg 1995;34:542–545.
13. Reid WH, McLeod PJ, Ritchie A, Ferguson-Pell M. Q-switched ruby laser treatment of black tattoos. Br J Plast Surg 1983;36:455–459.
14. Laub DR, Yules RB, Arras M, Murray DE, Crowley L, Chase RA. Preliminary histopathological observation of Q-switched ruby laser radiation on dermal tattoo pigment in man. J Surg Res 1968;8:220–224.
15. Taylor CR, Anderson RR, Gange W, Michaud NA, Flotte TJ. Light and electron microscopic analysis of tattoos treated by Q-switched ruby laser. J Invest Dermatol 1991;97:131–136.
16. Fitzpatrick RE, Goldman MP. Tattoo removal using the alexandrite laser. Arch Dermatol 1994;130:1508–1514.
17. Fitzpatrick RE, Goldman MP, Ruiz-Esparza J. Use of the alexandrite laser (755 nm, 100 nsec) for tattoo pigment removal in an animal model. J Am Acad Dermatol 1993; 28:745—750.
18. Chang SE, Choi JH, Moon KC, Koh JK, Sung KJ. Successful removal of traumatic tattoos in Asian skin with a Q-switched alexandrite laser. Dermatol Surg 1998;24: 1308–1311.
19. Leuenberger ML, Mulas MW, Hata TR, Goldman MP, Fitzpatrick RE, Grevelink JM. Comparison of the Q-switched alexandrite, Nd:YAG, and ruby lasers in treating blue-black tattoos. Dermatol Surg 1999;25:10–14.
20. Zelickson BD, Mehregan DA, Zarrin AA, Coles C, Hartwig P, Olson S, Leaf-Davis J. Clinical, histologic, and ultrastructural evaluation of tattoos treated with three laser systems. Lasers Surg Med 1994;15:364–372.
21. Alster TS. Cosmetic laser surgery. Adv Dermatol 1996; 11:51–80.
22. Anderson RR, Geronemus R, Kilmer SL, Farinelli W, Fitzpatrick RE. Cosmetic Tattoo ink darkening: a complication of Q-switched and pulsed-laser treatment. Arch Dermatol 1993;129:1010–1014.
23. Duke D, Urioste SS, Dover JS, Anderson RR. A reaction to a red lip cosmetic tattoo. J Am Acad Dermatol 1998; 39:488–490.
24. Kopera D, Hohenleutner U, Landthaler M. Quality-switched ruby laser treatment of solar lentigines and Becker's nevus: a histopathological and immunohistochemical study. Dermatology 1997;194:338–343.
25. Hakozaki M, Masuda T, Oikawa H, Nara T. Light and electron microscopic investigation of the process of healing of the naevus of Ota by the Q-switched alexandrite laser irradiation. Virchows Arch 1997;431:63–71.
26. Stafford TJ, Lizek R, Tan OT. Role of the alexandrite laser for removal of tattoos. Lasers Surg Med 1995;17: 32–38.
27. Troilius AM. Effective treatment of traumatic tattoos with a Q-switched Nd:YAG laser. Lasers Surg Med 1998; 22:103–108.
28. Achauer BM. Lasers in plastic surgery: current practice. Plast Reconstr Surg 1997;99:1442–1450.
29. Stafford TJ, Lizek R, Boll J, Tan OT. Removal of colored tattoos with the Q-switched alexandrite laser. Plast Reconstr Surg 1995;95:313–320.
30. Alster TS. Q-switched alexandrite laser treatment (755 nm) of professional and amateur tattoos. J Am Acad Dermatol 1995;33:69–73.
31. Taylor CR. Laser ignition of traumatically embedded firework debris. Lasers Surg Med 1998;22:157–158.